ATARNotes

# Chemistry 3/4

## Unit 3 Head Start

## January Lecture Series

Presented by:

Josh Hamilton

# Welcome!

# ATARNotes

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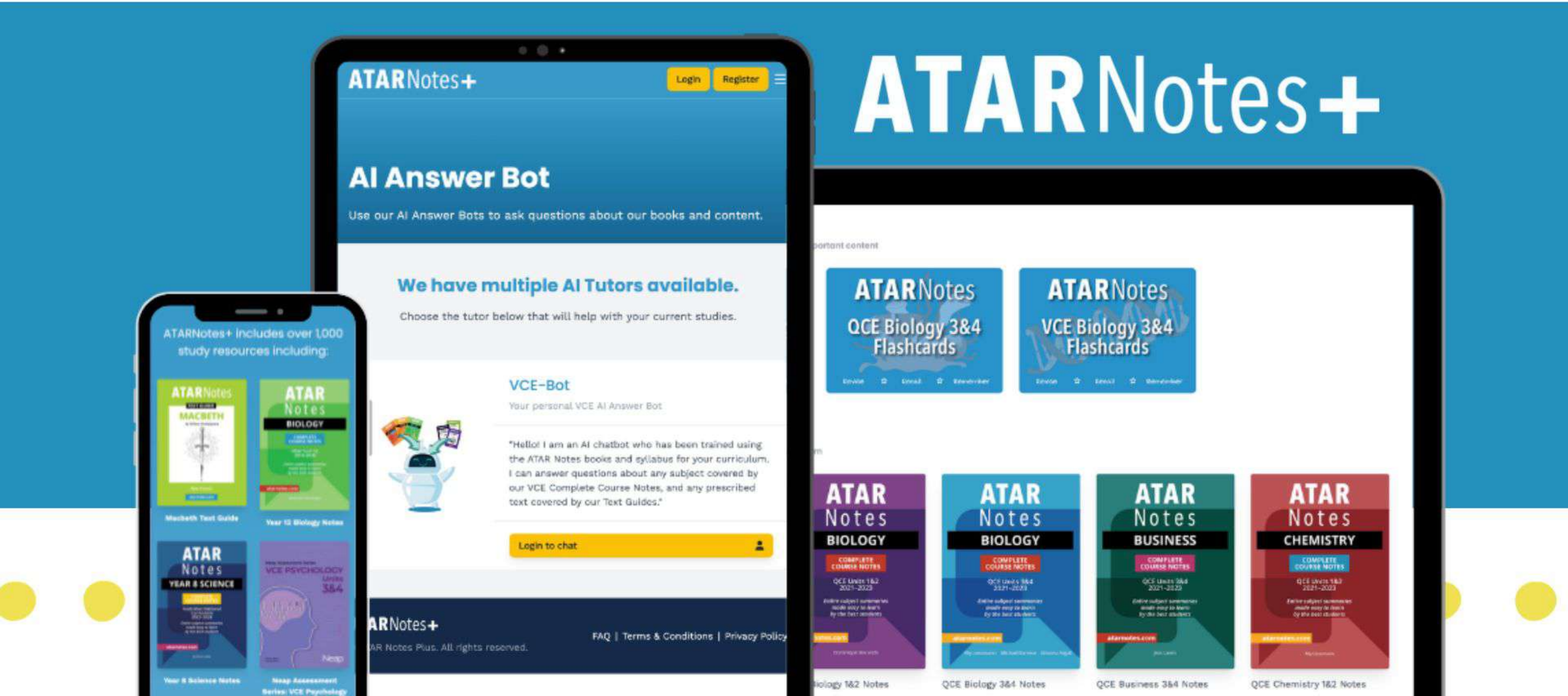


# Welcome!!

**Topics to be covered**

- Welcome to the Chemistry 3/4 head start lecture!
- First year of a new study design – following on from the Unit 1/2 changes you will have learnt last year

House keeping:

- Please feel free to utilise the chat to ask any questions
- The slides should be able to be accessed below
- This recording will be available after the premiere

# WHO AM I?

**BLOCK 1:**
**TIPS AND GREEN CHEM**

*40 minutes*

**BLOCK 2:**
**AOS1: FUELS AND NATURAL CYCLE**

*80 minutes*

# Todays Lecture

- It’s important to understand that today’s lecture won’t even cover all of Unit 3 AOS1…
- You might therefore be thinking, why are we even having this lecture?

- It’s important, at this stage of the year to build good strong habits
- That’s what I aim to do with these 2 hours

- To build an understanding of green chemistry – which will feature throughout every AOS
- To understand question technique and skills such as significant figures
- And then to give you a small head start on the content for the year!

# Tips and Changes

## Study Design

UNIT 3

FUELS → ELECTROCHEMISTRY → RATES & EQUILIBRIA

How chemistry powers our lives

UNIT 4

EXPERIMENTAL DESIGN → ORGANIC CHEM → ANALYTICAL CHEM

How chemistry explains life

## Changes made to the SD

### Unit 3 AOS1 Changes:

Removed:

- Emphasis on Crude Oil
- Emphasis on comparison of Cells

Added/Altered:

- Fuel sources pf the body (pulled from U4 AOS2)
- Cellular respiration and photosynthesis
- Green chemistry application

# Tips and Changes

## What to take from Unit 1/2

### NEED TO KNOW

- The concept of 'mole'
- Writing and balancing chemical equations
- Stoichiometric calculations, including working with moles, gases and concentrations
- HPLC
- Green chemistry

### HELPFUL TO KNOW

- Inter vs intramolecular bonds and strengths
- Redox basics – although completely covered again
- Organic basics – as above
- Acid Base Reactions

## How is Chemistry assessed?

UNIT 3 → UNIT 4 → EXAM

| UNIT 3 | UNIT 4 | EXAM |
| --- | --- | --- |
| *16%* | *24%* | *60%* |

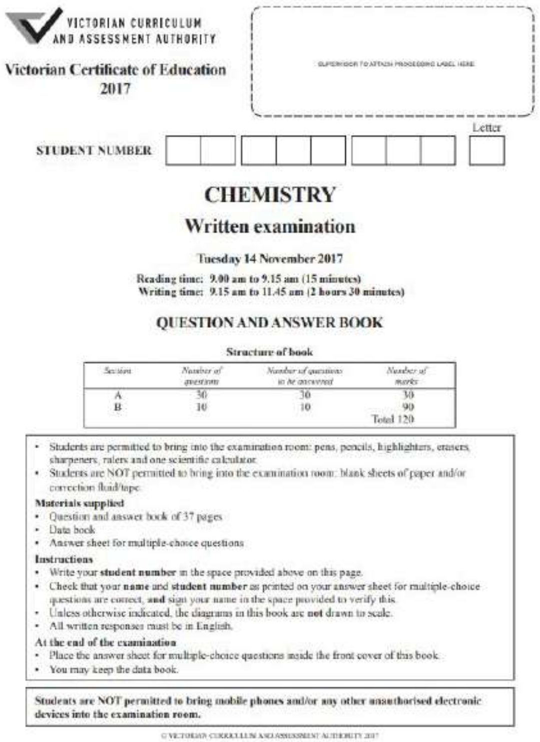
- Exam is the most important assessment
- Throughout the year, your end goal should be setting yourself up to do as well on the exam as possible!

# Tips and Changes

## What about the Exam?

- 120 marks in 150 marks + 15 reading
  - 30 MCQ
  - 90 SA marks (usually over 8-12 questions)

- The exam is difficult but also fair
  - There is a large variation in the questions
  - From straight forward recall-based questions to extremely complex interpretation-based questions
  - Although the questions are mostly segregated into topics, they do overlap at times so it’s important to practice integrating topics



VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2017

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER  Letter

**CHEMISTRY**

**Written examination**

**Tuesday 14 November 2017**

**Reading time: 9.00 am to 9.15 am (15 minutes)**
**Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)**

**QUESTION AND ANSWER BOOK**

**Structure of book**

| *Section* | *Number of questions* | *Number of questions to be answered* | *Number of marks* |
|---|---|---|---|
| A | 30 | 30 | 30 |
| B | 10 | 10 | 90 |
| | | | Total 120 |

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

**Materials supplied**
- Question and answer book of 37 pages.
- Data book.
- Answer sheet for multiple-choice questions.

**Instructions**
- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

**At the end of the examination**
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the data book.

**Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.**

# 3 Tips to Set up Success

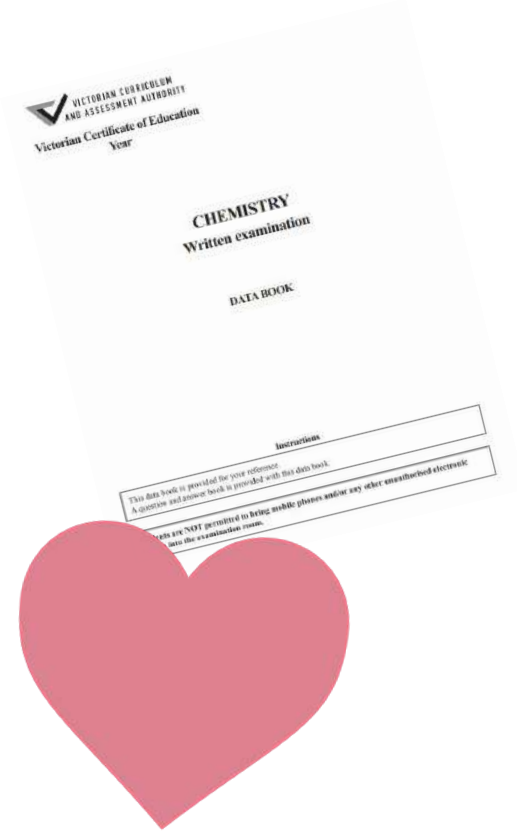
## 1. Work through the Study Design


- The study guide is intended as a guide… duh
- So, utilise it as one!

- The study guide has many examples, definitions and suggestions on how to learn the content required for the exam
- Utilise it as a checklist throughout the year and familarise yourself with the topics they emphasise throughout

## 2. Meet your new BFF

- If the SD does not become your best friend, the data booklet will
- This data booklet might look fairly foreign right now, but all the aspects covered in it will become super handy as you progress through the content
- Have one printed out early on that you label and annotate




- Note, in the exam you get a fresh new data booklet so no annotations will be useful then

## 3. Work hard but… more importantly, work efficiently!

- Prioritise study that will have the largest possible positive impact on your results
- This means to focus on areas you struggle with (even if you dislike the content)

- Practice throughout the year. Learning to answer questions is a skill itself, don't leave it until just before exams!
- Always review SACs, focus on the errors you made under pressure

# Significant Figures

There are **three** significant figure rules

1. Non-zero digits always significant: eg// 11, 3, 451.11
2. Any zeroes between two significant digits are significant: e.g. 10100, 2201, 0.3401
3. A zero which is after a significant figure AND after a decimal point is significant: eg// 3.00, 4.40, 24.30, 0.01200, 0.99700

Example: 30.0 – how many sigfigs?

- The 3 is non-zero so significant
- The first 0 (at first) seems not significant
- The second 0 is after a significant zero AND after a decimal point
- Then going back to the first 0, it is between two significant figures so its significant
- Thus, there are three sig figs

# Significant Figures

**Multiplication and division**

- Answer has **least number of significant figures**

$$\frac{2.47}{1.299} = 1.901462$$

**Addition and subtraction**

- Answer has **least number of decimal places**

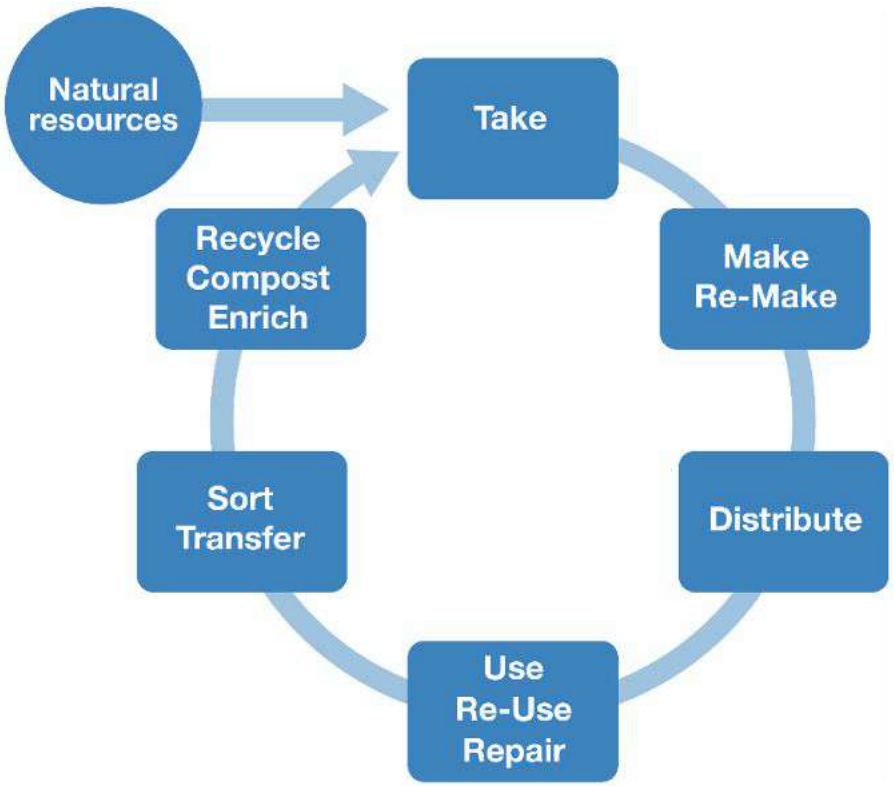
$$1.21 + 2.443 + 3.1 = 6.753 \approx 6.8$$

# Green Chemistry

# Green Chemistry

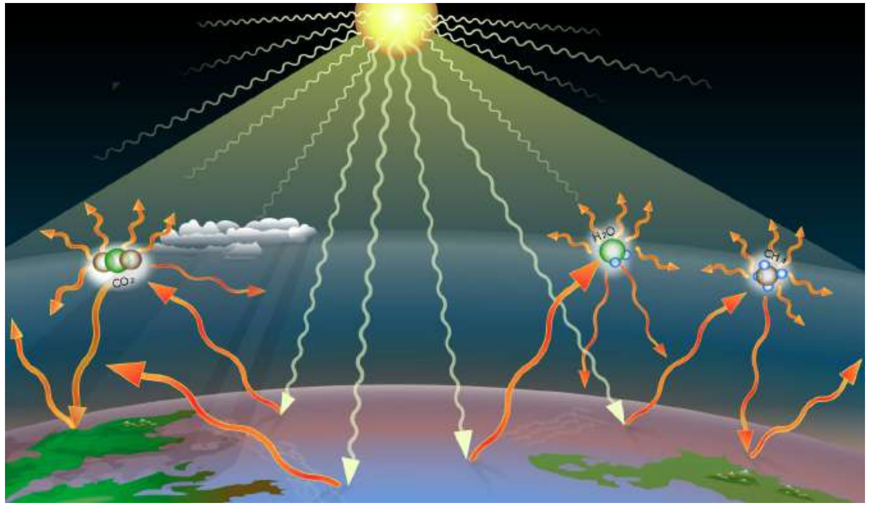
- ‘A continuous cycle that focuses on the optimal use and re-use of resources from the extraction of raw materials through to production of new materials, followed by consumption and re-purposing of unused and waste materials.’

- This is an exact extract of the VCAA study design



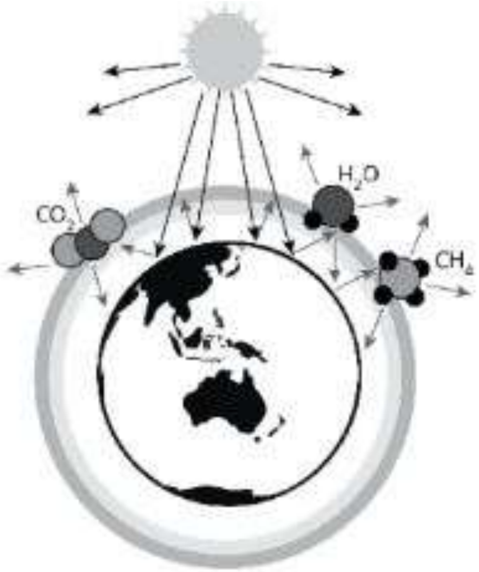
**Greenhouse gases** are gases in the earth's atmosphere that absorb and trap heat, assisting to regulate and ensure that the planet has is at a sufficient temperature

- During the day the Sun's UV rays heat up the earth
- At night, this heat is released back into the atmosphere, without GHGs, the heat would rise and be released from our atmosphere
- GHGs ensure that this does not happen completely, trapping a portion of the heat



# Enhanced Greenhouse Effect

**The enhanced greenhouse effect** is what we currently refer to as the major cause of climate change – it is due to an increased production of greenhouse gases, particularly fluorinated gases, from fuel and infrastructure production




- The increased ability for the planet to absorb and retain infrared radiation has subsequently begun to slowly warm the planet
- This has shifted climate norms and increased sea levels
  - This is due to glacier melting from increased pole temperatures

## VCAA Expectations

- The new VCAA study design places significance on green chemistry principles, below are the concepts you should by the end of the year understand:

  - Atom Economy
  - Catalysis
  - Design for degradation
  - Design for energy efficiency
  - Designing safer chemicals
  - Prevention
  - Use of renewable feedstocks

# Green Chemistry

## Match the GCP to Definition

| | Concept |
|---|---|
| 1 | Atom Economy |
| 2 | Catalysts |
| 3 | Design for Degradation |
| 4 | Design for Energy Efficiency |
| 5 | Designing Safer Chemicals |
| 6 | Prevention |
| 7 | Use of Renewable Feedstock |

| | Concept |
|---|---|
| A | Chemical products should be designed so that at the end of their use they break down into harmless degradation products and do not persist in the environment. |
| B | These should be selected to generate the same desired product(s) with less waste and using less energy and reagents in reaction processes. |
| C | Chemical products should be designed to achieve their intended function while minimising toxicity. |
| D | Raw materials or feedstocks should be made from renewable (mainly plant-based) materials, rather than from fossil fuels, whenever practicable. |
| E | Processes should be designed for maximum energy efficiency and with minimal negative environmental and economic impacts. |
| F | It is better to prevent waste than to treat or clean up waste after it has been produced. |
| G | Processes should be designed to maximise incorporation of all reactant materials used in the process into the final product. |

# Green Chemistry

## Topics Explicitly in the 3/4 SD

- The VCAA Dot Points for 3/4 have 3 explicit examples of green chemistry you must know for the end of year exam.

1. Fuel Cell Sustainability
   - Catalysts, Design for Energy Efficiency and Use of Renewable Feedstock
2. Equilibria in Industry
   - Catalysts, Atom Economy and Design for Energy Efficiency
3. Green Hydrogen
   - Design for Safer Chemicals and Use of Renewable Feedstock

ATAR Notes

***Area of Study 1***

# What are the current and future options for supplying energy?

ATAR Notes

# 1. Fuels and Thermochemistry

## What is a fuel?

- **Definition:** A fuel is a substance that can be reacted with other substances (eg// $O_2$), leading to the release of energy that can be harnessed for a specific purpose.
  - This is explicitly mentioned in the SD as a definition you must know

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**RENEWABLE**

A renewable resource can be replenished by natural processes within a relatively short period of time.

(short period = human lifetime)

**NON-RENEWABLE**

A non-renewable resource cannot be replenished by natural processes within a relatively short period of time.

# Biofuels and Fossil Fuels

**BIOFUELS**

Fuels derived from living matter compressed underground for millions of years.

**FOSSIL FUELS**

Derived from plant matter and can be produced at the same rate we consume it.

**BIOFUELS**

- Biogas
- Bioethanol
- Biodiesel

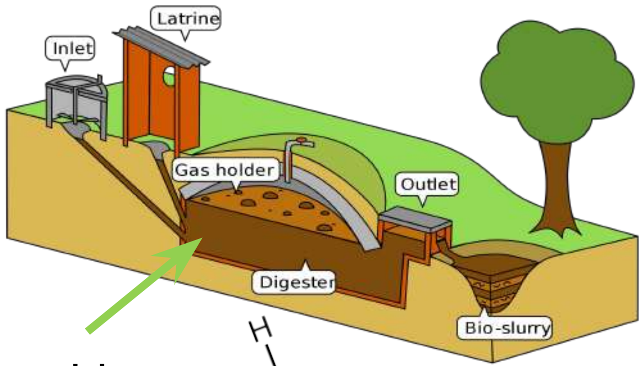
**FOSSIL FUELS**

- Natural Gas
- Coal
- Petrol

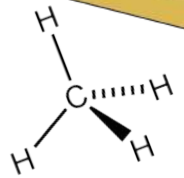
# Fuels and Thermochemistry

## Biogas and Bioethanol

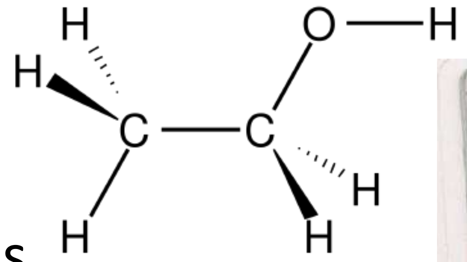
- **Biogas** – produced via anaerobic fermentation of plant waste by anaerobic bacteria producing methane (32%)
  - Releases far less energy than Natural Gas
  - Waste sources from sewage treatment plants and landfill in Australia




Anaerobic bacteria



- **Bioethanol** – produced via anaerobic fermentation of glucose by yeast
  - The bioethanol must be distilled prior to use
  - This involves boiling product through large tubes and pipes, allowing for the water to move to one area and the ethanol to another

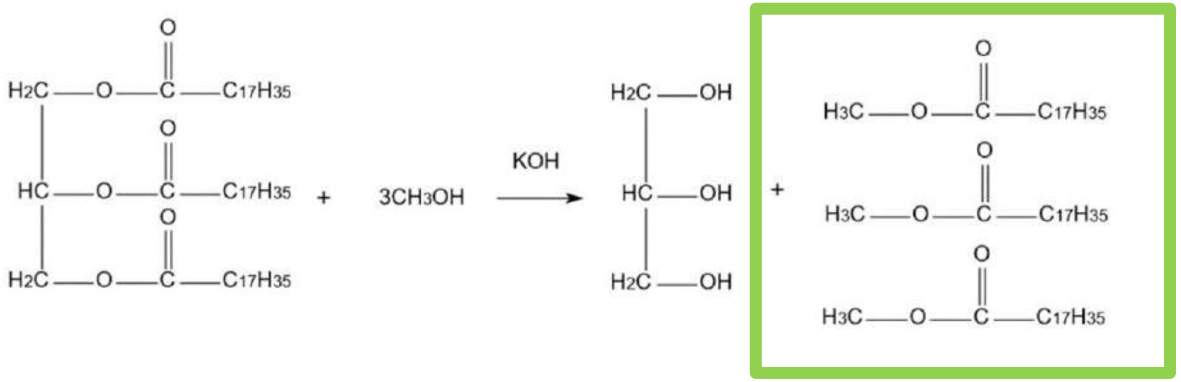


# Biodiesel

- **Biodiesel** – Produced by using plant oils or animal fats (triglycerides) in a **transesterification reaction** (Unit 4 AOS1)

*Triglyceride + Methanol → Glycerol + Biodiesel*

  - Biodiesel is polar compared to petrol (similar energy content) which is non-polar, this produces issues such as greater viscosity (thickness) and hygroscopicity (absorption of energy)



# Fuels and Thermochemistry

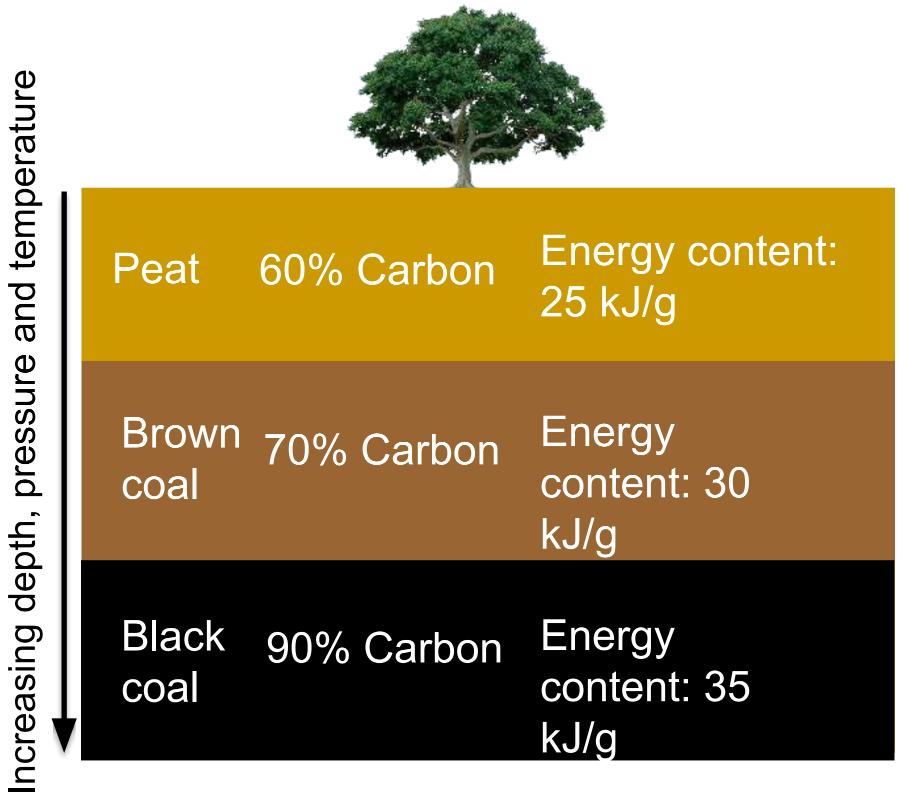
## Coal

- **Coal** – a combustible black or brown rock composed primarily of carbon
  - Largest source of energy for the generation of electricity worldwide

- Must know the energy transformation pathway:

*Chemical → Thermal (coal) → Thermal (steam)*

*→ Mechanical (turbine coil) → Electrical*



# Natural Gas and Petrol

- **Natural Gas** – a wide variety of hydrocarbon gases (methane → butane) utilised as fuel
  - Found in ground pockets
  - Composed of extremely high percentage of fuel (eg//methane) compared with biogas

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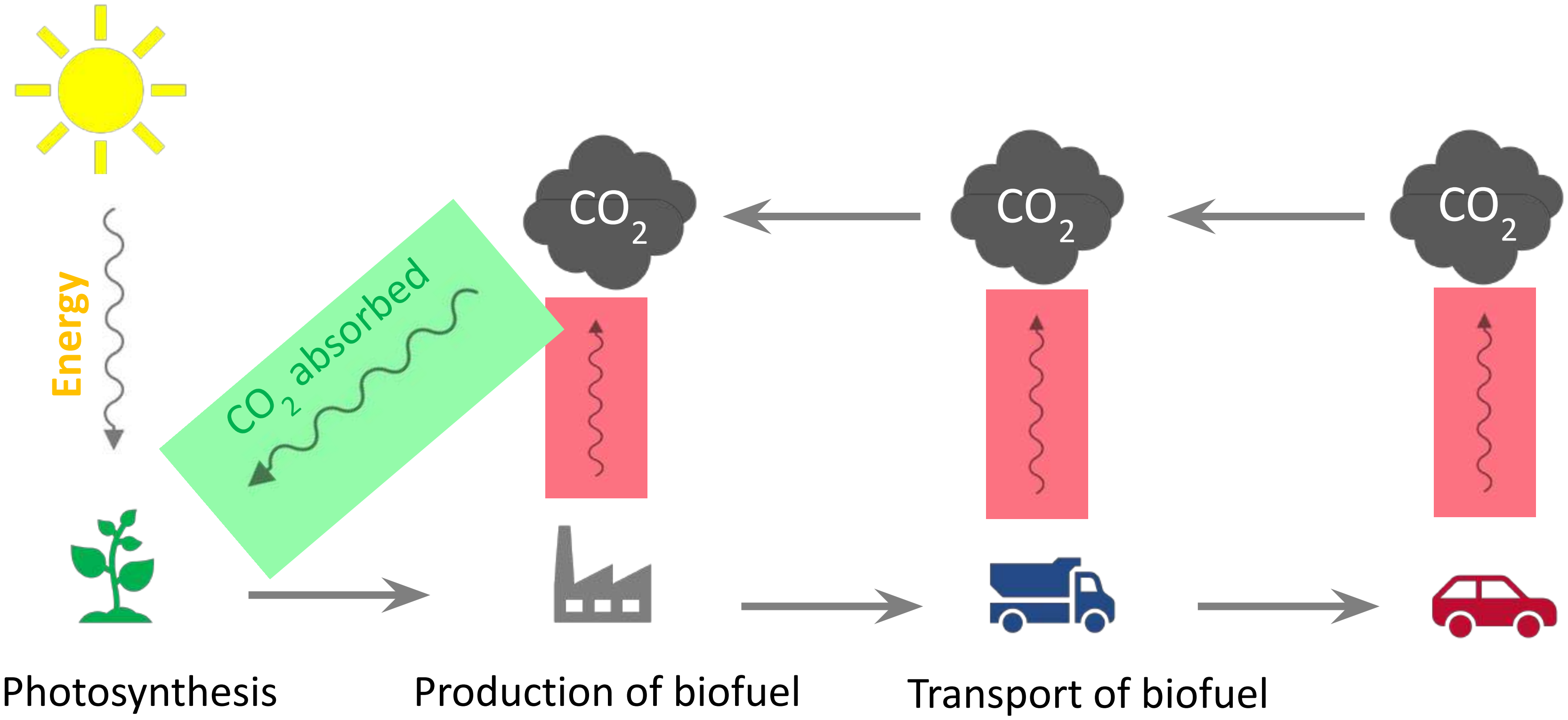
- **Petrol** – refined version of oil that is collected from large deposits under the ocean (oil rigs)
  - Raw product = crude oil / petroleum (mixture of hydrocarbons)
  - Refined product = **petrol**, petrodiesel (most common) and diesel
    - Each are a collection of same length hydrocarbons

# Carbon Neutral

**Carbon Neutral** refers to the recycling of carbon, the carbon released as a greenhouse gas ($CO_2$) is approximately the same amount absorbed during the process of fuel creation



# Features of Fuels

- If asked to compare fuels, these are the features you must consider:
  - **Renewability**
  - **Energy content** – general rule, fossil fuel > biofuel
  - **Fuel structure** – most biofuels are polar, most fossil fuels are non-polar
  - **Viscosity** – the thickness and flow of a fuel (stronger bonds, more thick)
  - **Interactions** – polarity and environmental water(known as hygroscopicity)
  - **Boiling Point** –more bonds, higher boiling point
  - **Combustion products** – fossil fuels contain more particulates and damaging greenhouse gases

# Comparing Questions

- For this topic, VCAA has in the past been particularly keen to test your ability to ***compare*** fuels
  - Admittedly, this seems to be significantly reduced in the new SD but it is still worth practicing as it applied to all comparison questions in chemistry
  - So, when answering questions, make sure you actually compare!

Example question: With reference to chemical structure, <u>*compare*</u> the suitability of biodiesel and petrodiesel as fuels to power vehicles in cold climates.

No comparison: Petrodiesel only experiences weak dispersion force attractions. Thus it has a lower cloud point, making it more suitable for use at low temperatures.

Good comparison: <u>***While biodiesel experiences dipole – dipole attractions***</u>, petrodiesel only experiences weaker dispersion forces. Thus, petrodiesel has a lower cloud point <u>***than biodiesel***</u>, making it a more suitable fuel at low temperatures.

# Fuels and Thermochemistry

How do we release the energy from fuels?

~~SET IT ON FIRE~~

Combustion!

## Combustion Reactions

*__Complete__* combustion reactions (burning stuff) always follow the general form:

$$\text{hydrocarbon} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water}$$

Example:

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$$

| Reactants | | Products |
|---|---|---|
| 2 C | ✓ | 2 C |
| 6 H | ✓ | 6 H |
| 7 O | ✓ | 7 O |

**BALANCED**

Note: Must always ensure equation is balanced, this is ***SUPER IMPORTANT***!

Write out the equation for the incomplete combustion of heptane.

BUT….

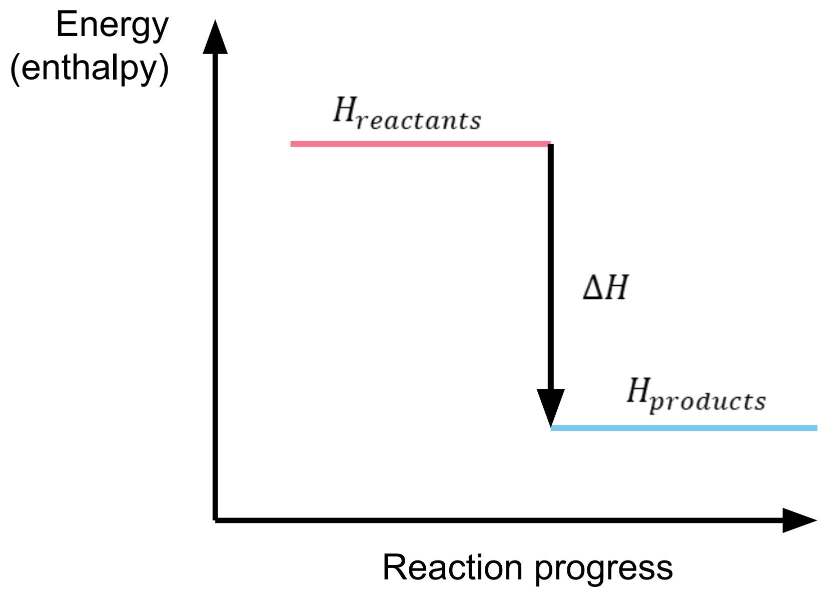
# Enthalpy

- Enthalpy refers to energy and change refers to change
  - Simply, **enthalpy change = energy change = $\Delta H$**

- Any reaction that **releases** energy, including combustion reactions, are known as **exothermic** reactions
- Any reaction that **absorbs** energy, including photosynthesis, are known as **endothermic** reactions

- $\Delta H$ is placed at the end of a thermochemical equation
- $\Delta H_c$ is utilised for molar values (standard values)

- Exothermic reactions release energy, therefore, the chemical equation system 'loses energy'
  - All combustion reactions are exothermic



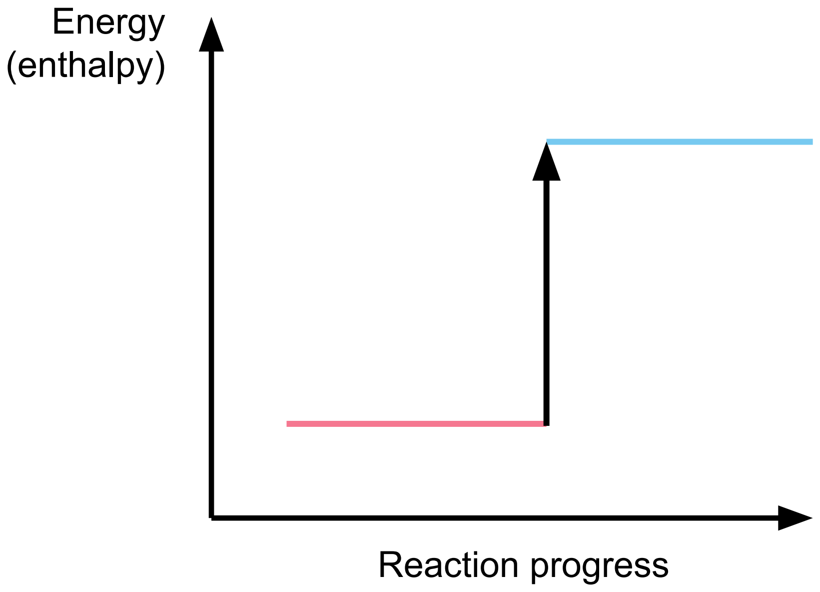

$$\Delta H = H_{\mathbf{products}} - H_{\mathbf{reactants}}$$

EXOTHERMIC REACTION

$$\Delta H < 0$$

# Endothermic Reactions

- Endothermic reactions absorb energy, therefore, the chemical equation system 'gains energy'




$$\Delta H = H_{\text{products}} - H_{\text{reactants}}$$

**ENDOTHERMIC REACTION**

$$\Delta H > 0$$

**Question 6**

The equation for the combustion of methane is

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g), \Delta H = -889 kJ/mol$$

A **plausible** interpretation of this thermochemical equation is:

1 mark

**A.** 800 kJ/mol is used to break existing bonds in $CH_4$ but not in $O_2$ (as $O_2$ is a pure element), and 1689 kJ/mol is released when the products are formed.

**B.** 450 kJ/mol is released when bonds are broken, and another 439 kJ/mol is released when bonds are formed to produce $CO_2$ and $H_2O$.

**C.** No energy is used to break existing bonds because the products are lower in energy than the reactants, and 889 kJ/mol is released when the products are formed.

**D.** 1680 kJ/mol is used to break existing bonds in $CH_4$ and $O_2$, and 2569 kJ/mol is released when bonds are formed to produce $CO_2$ and $H_2O$.

## Thermochemical Equation

- A **thermochemical equation** is made up of 2 parts:

$$\underbrace{CH_{4(g)} + 2O_{2(g)} \rightarrow 2H_2O_{(g)} + CO_{2(g)}}_{\text{1. Chemical equation}} \quad \underbrace{\Delta H = -890\ \text{kJ/mol}}_{\text{2. Enthalpy change value}}$$

- Enthalpy change is measured in the units of kJ/mol but also in kJ/gram
- **ΔH** changes with as the co-efficent of fuel changes

$$2CH_{4(g)} + 3O_{2(g)} \rightarrow 4H_2O_{(g)} + 2CO_{2(g)} \quad \Delta H = -1780\ \text{kJ/mol}$$

- **Multiply coefficients ⇒ multiply ΔH**

$6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(s)} + 6O_{2(g)}$, $\Delta H = +2803\ \text{kJ mol}^{-1}$

$12CO_{2(g)} + 12H_2O_{(l)} \rightarrow 2C_6H_{12}O_{6(s)} + 12O_{2(g)}$, $\Delta H = +5606\ \text{kJ mol}^{-1}$

- **Reverse the equation ⇒ flip the sign of ΔH**

$6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(s)} + 6O_{2(g)}$, $\Delta H = +2803\ \text{kJ mol}^{-1}$

$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(l)}$, $\Delta H = -2803\ \text{kJ mol}^{-1}$

**Question 15** Beware

By using **enthalpy changes of formation**, we can calculate values for the $\Delta H$ of any given reaction. Given the reaction of dinitrogen tetroxide to form nitrous oxide ($N_2O$) and ozone ($O_3$), and the reactions for forming these chemical species respectively from their elements, calculate a value for $\Delta H$ of the reaction:

$$N_2O_4(g) \rightarrow N_2O(g) + O_3(g)$$

- $N_2(g) + 2O_2(g) \rightarrow N_2O_4(g)$, $\Delta H = +11.1 kJ/mol$
- $2N_2(g) + O_2(g) \rightarrow 2N_2O(g)$, $\Delta H = +163.2 kJ/mol$
- $3O_2(g) \rightarrow 2O_3(g)$, $\Delta H = +285.4 kJ/mol$

5 marks

Question source: ATAR Notes Topic Tests

# Practice Question

**Question 15** Beware

By using **enthalpy changes of formation**, we can calculate values for the $\Delta H$ of any given reaction. Given the reaction of dinitrogen tetroxide to form nitrous oxide ($N_2O$) and ozone ($O_3$), and the reactions for forming these chemical species respectively from their elements, calculate a value for $\Delta H$ of the reaction:

$$N_2O_4(g) \rightarrow N_2O(g) + O_3(g)$$

- $N_2(g) + 2O_2(g) \rightarrow N_2O_4(g)$, $\Delta H = +11.1\text{kJ/mol}$
- $2N_2(g) + O_2(g) \rightarrow 2N_2O(g)$, $\Delta H = +163.2\text{kJ/mol}$
- $3O_2(g) \rightarrow 2O_3(g)$, $\Delta H = +285.4\text{kJ/mol}$

5 marks

Question source: ATAR Notes Topic Tests

# Fuels and Thermochemistry

## 11. Heats of combustion of common fuels

The heats of combustion in the following table are calculated at SLC (25 °C and 100 kPa) with combustion products being $CO_2$ and $H_2O$. Heat of combustion may be defined as the heat energy released when a specified amount of a substance burns completely in oxygen and is, therefore, reported as a positive value, indicating a magnitude. Enthalpy of combustion, $\Delta H$, for the substances in this table would be reported as negative values, indicating the exothermic nature of the combustion reaction.

| Fuel | Formula | State | Heat of combustion ($kJ\ g^{-1}$) | Molar heat of combustion ($kJ\ mol^{-1}$) |
|---|---|---|---|---|
| hydrogen | $H_2$ | gas | 141 | 282 |
| methane | $CH_4$ | gas | 55.6 | 890 |
| ethane | $C_2H_6$ | gas | 51.9 | 1560 |
| propane | $C_3H_8$ | gas | 50.5 | 2220 |
| butane | $C_4H_{10}$ | gas | 49.7 | 2880 |
| octane | $C_8H_{18}$ | liquid | 47.9 | 5460 |
| ethyne (acetylene) | $C_2H_2$ | gas | 49.9 | 1300 |
| methanol | $CH_3OH$ | liquid | 22.7 | 726 |
| ethanol | $C_2H_5OH$ | liquid | 29.6 | 1360 |

A lot of these are gases… what if we have to work with them?

# Universal Gas Equation

- The **Universal Gas Equation**:

$$PV = nRT$$

Where:

- **P** = Pressure (kPa)
- **V** = Volume (L)
- **n** = moles
- **R** = Ideal Gas Constant (8.31)
- **T** = Temperature (K)

# Practice Question

A 250.0 mL compressed air canister contains $CO_2$ stored at 10.2 atm, and at room temperature (25°C). Find the mass of $CO_2$ in the canister.

## Practice Question

A 250.0 mL compressed air canister contains $CO_2$ stored at 10.2 atm, and at room temperature (25°C). Find the mass of $CO_2$ in the canister.

$PV = nRT$ □ $n = PV / RT$

- $P = 1033.4$ kPa | $V = 0.25$L | $T = 298$K

- $n = (1033.4 \times 0.25) / (8.31 \times 298)$
- $n = 0.104$
- $m(CO_2) = 0.104 \times 44$
- $= 4.59$g

## Molar Volume

- In many cases, we will be given a **Universal Gas Equation** question and told the conditions are at **SLC (Standard Lab Conditions)**
  - $25^{O}C$ or 298K
  - 100 kPa
  - 1M Concentration of Liquids

- So, how do we go about these questions?
  - You can go about it the long way, inputting 298K and 100 kPa
  - Or we can use the molar volume equation

$$V = n \times V_m \quad \text{where } V_m = 24.8$$

# 2. Food Chem

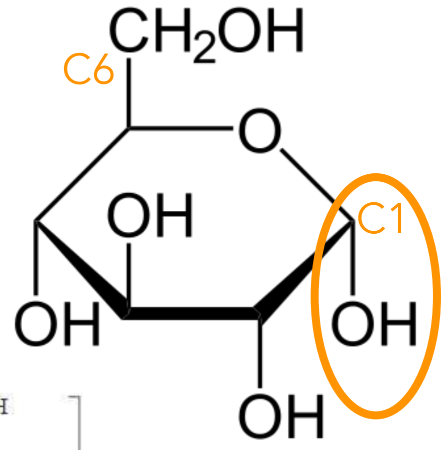
# Food Chemistry

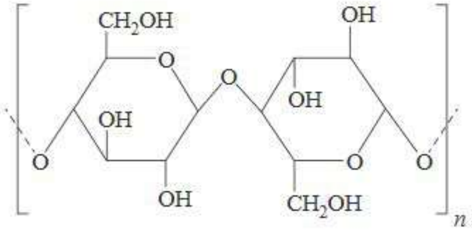
Fooooood

- **Food** is the fuel of the human body, our primary source of energy
- We have three main macromolecules in which we obtain energy from:
  - **Carbohydrates**
  - **Proteins**
  - **Fats (Lipids)**
- In order to utilise these, we must first break them down from food sources into monomers
  - **Monomers** = individual units
    - Eg// Amino Acids, Glucose
  - **Polymers** = larger complete products
    - Eg// Enzymes, Starch

- The pathway of food breakdown to storage is still covered in Unit 4


- **Carbohydrates** in non-science / familiar terms are sugars and are the primary energy source of the body
  - They are made up of monomers of monosaccharides, most commonly glucose ($C_6H_{12}O_6$)
  - Polymers are polysaccharides and vary dependent on location of creation
- $\alpha$-glucose is the form of glucose utilised in the human body
  - Alpha refers to the C1–OH group spatial location
- Polymers can be disaccharides (2) or polysaccharides
  - Starch – plants (digestible)
  - Cellulose - plants (fibre) (β-glucose)
  - Glycogen – humans



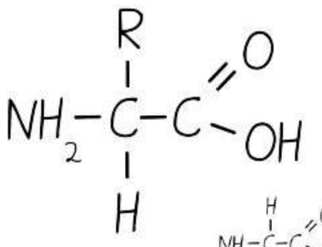

cellulose

# Food Chemistry

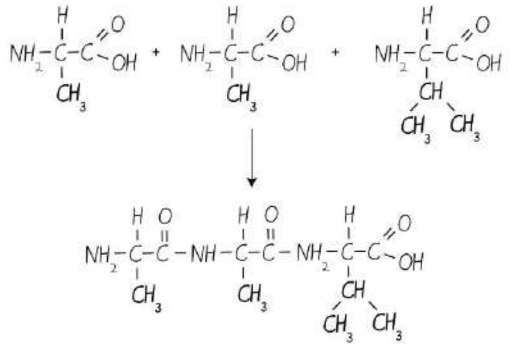
## Proteins

- **Proteins** are the building blocks of life they form important enzymes that catalyse reactions, molecule carriers (such as Haemoglobin carrying oxygen in the blood) and structural components of the body
    - These consist of $\alpha$-amino acids (monomer)
    - 20 exists in the body, 11 of these are non-essential (can be created by the body where necessary) and 9 are essential (must be possessed through our diet)
    - All $\alpha$-amino acids are found on page 14-15 of the data booklet

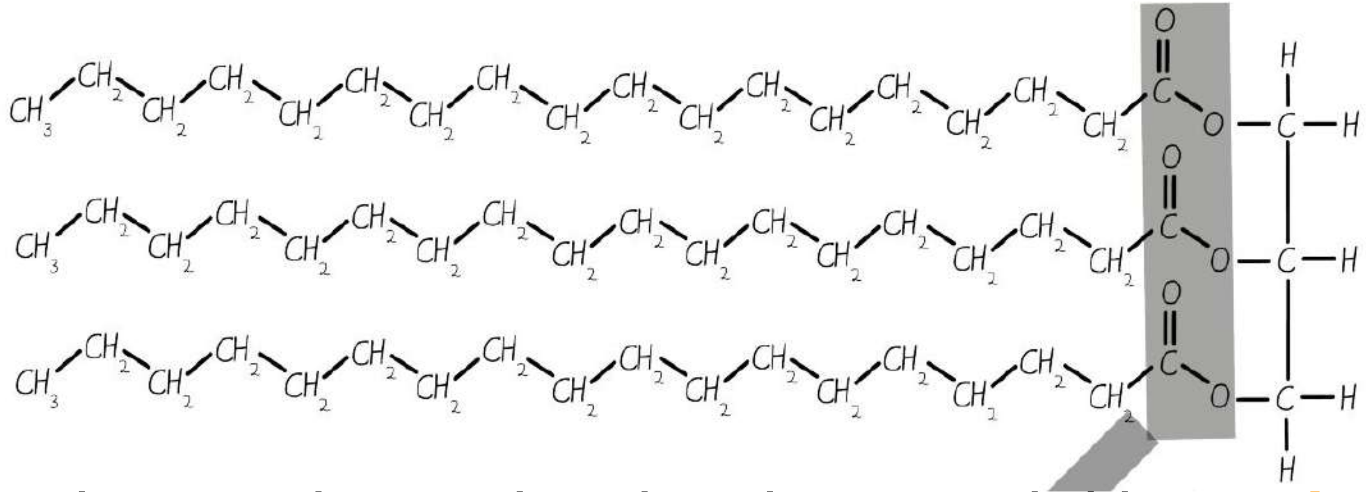
- All $\alpha$-amino acids have a general structure like this:



- Because we have so many amino acids, the order in which they are put together to form a protein is important and unique:



- **Fats (Lipids)**, specifically Triglycerides, are made up of 3x fatty acids and a glycerol molecule
  - Despite these components being referred to as monomers, they technically do not meet the criteria



- **Fats** are deeply complex molecules that, much like **Carbohydrates** and **Proteins**, will be further unpacked in Unit 4 AOS1

# How much Energy?

- Throughout Chemistry 3/4, we will utilise the following energy content values supplied in Page 10 of the Data Booklet:

**13. Energy content of food groups**

| Food | Heat of combustion ($kJ\ g^{-1}$) |
|---|---|
| fats and oils | 37 |
| protein | 17 |
| carbohydrate | 16 |

## How do we measure the energy from food?

- Calorimetry is used to measure the energy change in a substance when it undergoes a reaction
  - Generally utilised in substances with unknown / variable molar masses

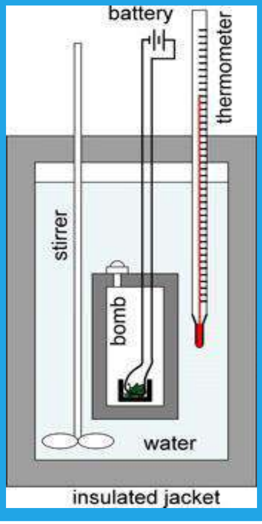
- Calorimetry comes in two forms:
  - Bomb
  - Solution

- Basic Methodology of Calorimetry:

1. Inside the calorimeter is a **known** volume of water
2. A sample inside reacts and releases / absorbs energy
3. Exchange of energy alters the temperature of the water

## Bomb Calorimetry

- Utilised for heat of combustion
- Contains vessel (bomb) in which fuel is placed
- High pressure oxygen and ignition wires ignite the fuel
- Heat released exits vessel and heats surrounding water



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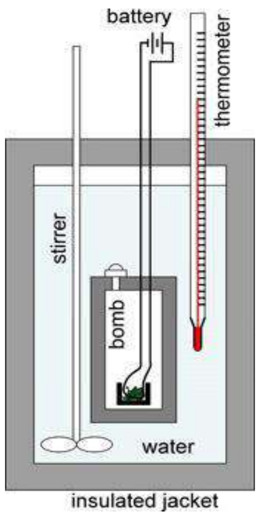


## Solution Calorimetry

- Similar to bomb calorimetry but in this case the reaction occurs within the solution
- A stirrer is particularly important for this case
- A thermometer is used to measure temperature change

# Calibration Factors

- Calorimeters require calibration prior to use
- To calculate a **calibration factor**, we run a wire through the calorimeter and pass a set amount of electricity through, measuring the temperature change

$$E = VIt$$

- E = energy in joules
- V = voltage in volts
- I = current in amps
- t = time in seconds

$$C.F = VIt / \Delta T$$

$$C.F = E / \Delta T$$

- C.F = calibration factor in J/K
- E = energy in joules
- ΔT = change in temperature in Kelvin

## Specific Heat Capacity of Water

- Recall from Chemistry Units 1&2 that the **specific heat capacity of water** is the amount of thermal energy required to heat up 1.00 g of water by 1.00$^{O}$C, which is 4.18 J

- We can use the **specific heat capacity of water** to estimate the approximate amount of energy released as heat in a combustion reaction
  - This is particularly useful in **food** chemistry to determine how much energy has been released

# Specific Heat Capacity Equation

$$q = mc\Delta T$$

Where:

- $q$ = energy in joules
- $m$ = mass in grams
- $c$ = specific heat capacity in J/g/K
- $\Delta T$ = change in temperature in Kelvin or $^{O}C$

- Reminder: Water's constant is **4.18**

## Practice Question

A 1.56 g sample of a hydrocarbon mixture (which includes methane and ethane) is burnt. The heat produced was used to heat up a 2L container of water, initially at 20$^{O}$C. The final temperature of the water was 55$^{O}$C.

Determine the energy content of the fuel in kJ $g^{-1}$.
Assume all the energy released was transferred to the water.

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Determine the energy content of the fuel in $kJ\ g^{-1}$.
Assume all the energy released was transferred to the water.

- m(water) = 2 x 0.987 □ = 1.974 kg or 1974g
- q = 1974 x 4.18 x 35 □ = 289000J or 289kJ
- $\Delta H_{Solution}$ = 289 / 1.56 □ = 185 kJ/g

# 3. Natural Cycle

# Natural Cycle



- Humans require glucose as an energy source
  - Every action, even using your hand to click play on this video needs energy

- Glucose has a very interesting cycle in the natural world, from production to use in the body and back to production

# Natural Cycle

- All life requires energy and organic molecules for growth, development and maintenance. In almost all cases this energy is found in the form of glucose!
- All animals and fungi, whether they are herbivores or carnivores are heterotrophs, meaning they obtain their nutrients (glucose and more) by consuming other organisms
- Plants however are autotrophs, meaning that they produce their own organic molecules and source of ATP
  - Autotrophs are the ultimate source of energy for all animals

# Photosynthesis

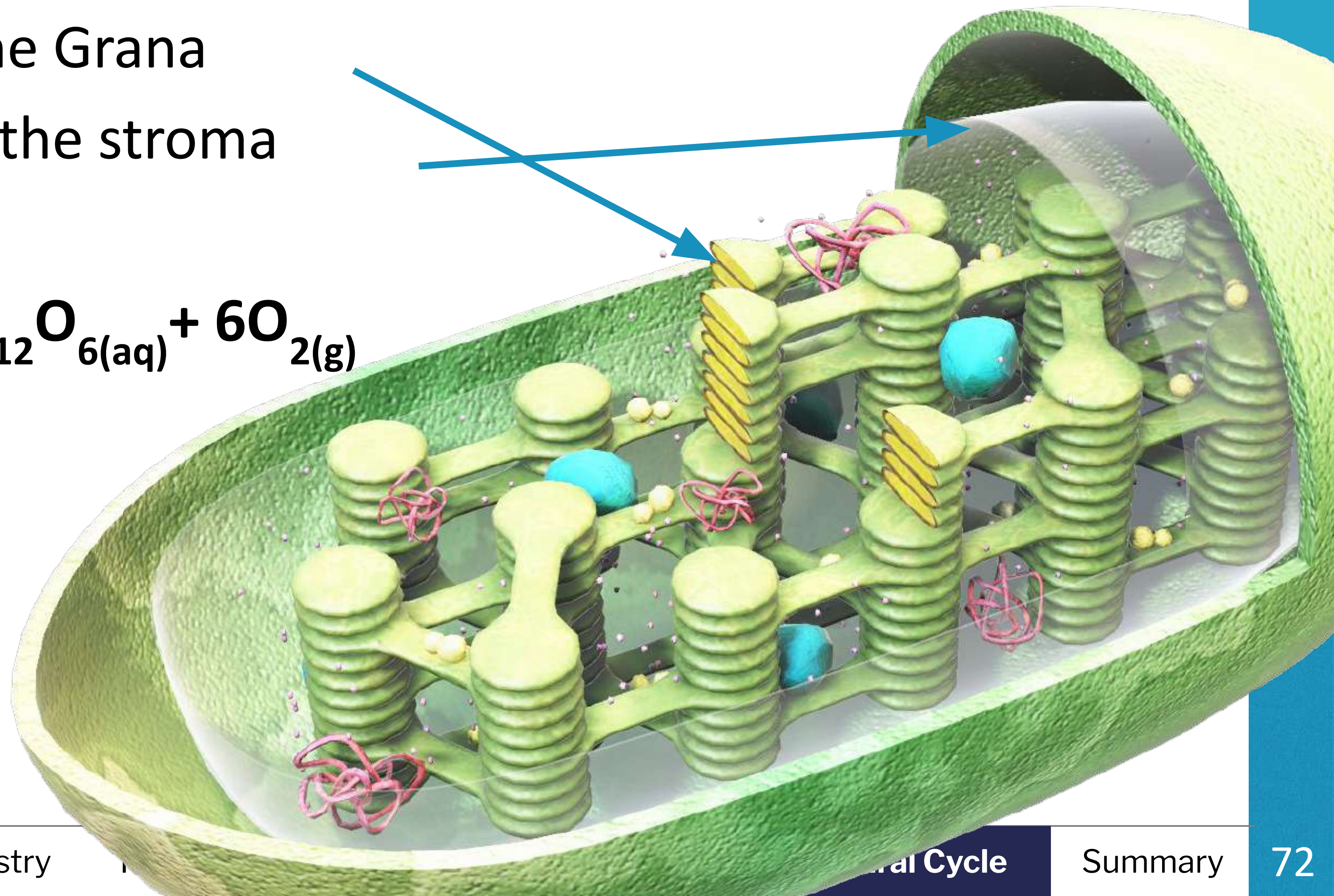
- **Photosynthesis** is the process of converting **light energy** into **chemical energy**
- This is achieved by harnessing the sun's light to convert $\mathbf{CO_2}$ into **glucose**
- Photosynthesis occurs in the **chloroplast** of plant cells, an organelle us humans do not have

# Photosynthesis

Photosynthesis occurs in two stages:

- **Light Dependent** – in the Grana
- **Light Independent** – in the stroma

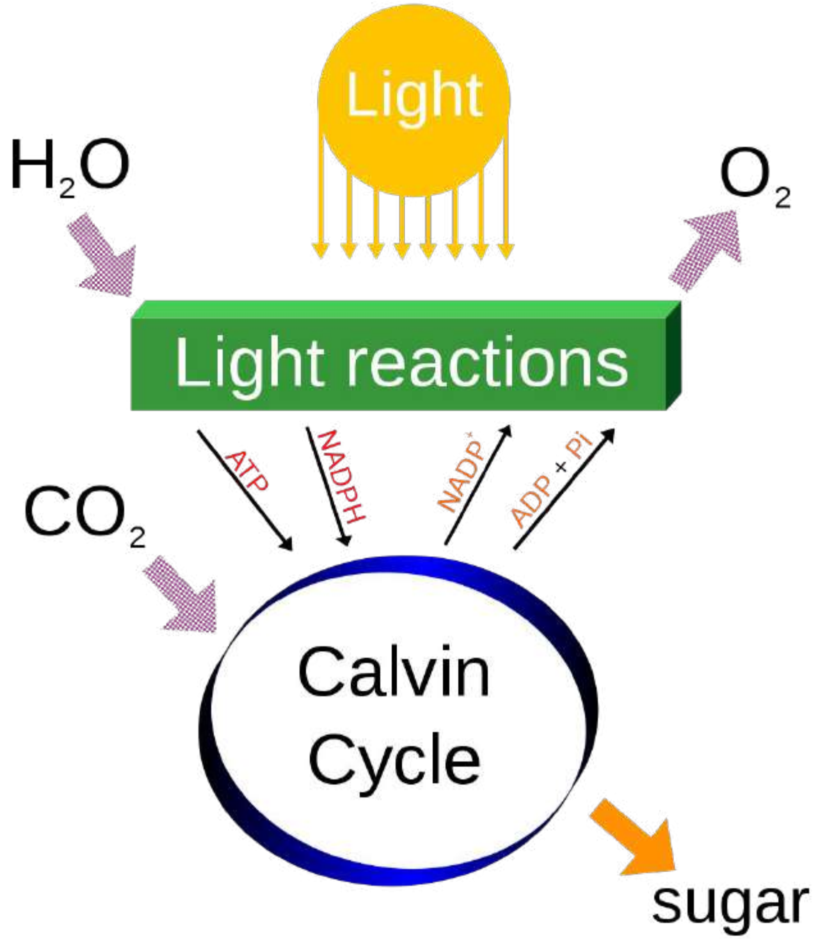
- $6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(aq)} + 6O_{2(g)}$



# Photosynthesis is a Cycle

- Importantly, you must understand that photosynthesis is a **cycle**, and each stage depends one the other
  - If one input is limited, the whole process reduces

| STAGE | INPUTS | OUTPUTS | SITE |
|---|---|---|---|
| **LIGHT DEPENDENT** | Water, ADP + Pi, $NADP^+$ | Oxygen, NADPH, ATP | Grana |
| **LIGHT INDEPENDENT** | Carbon dioxide, ATP, NADPH | Glucose, ADP + Pi, $NADP^+$ | Stroma |



# Aerobic Respiration

- Aerobic Respiration is an extremely complex pathway of converting glucose into **ATP** – the source of utilisable energy in human muscle cells
  - This is an '**oxidative process**'
  - This makes the entire process a **redox reaction**

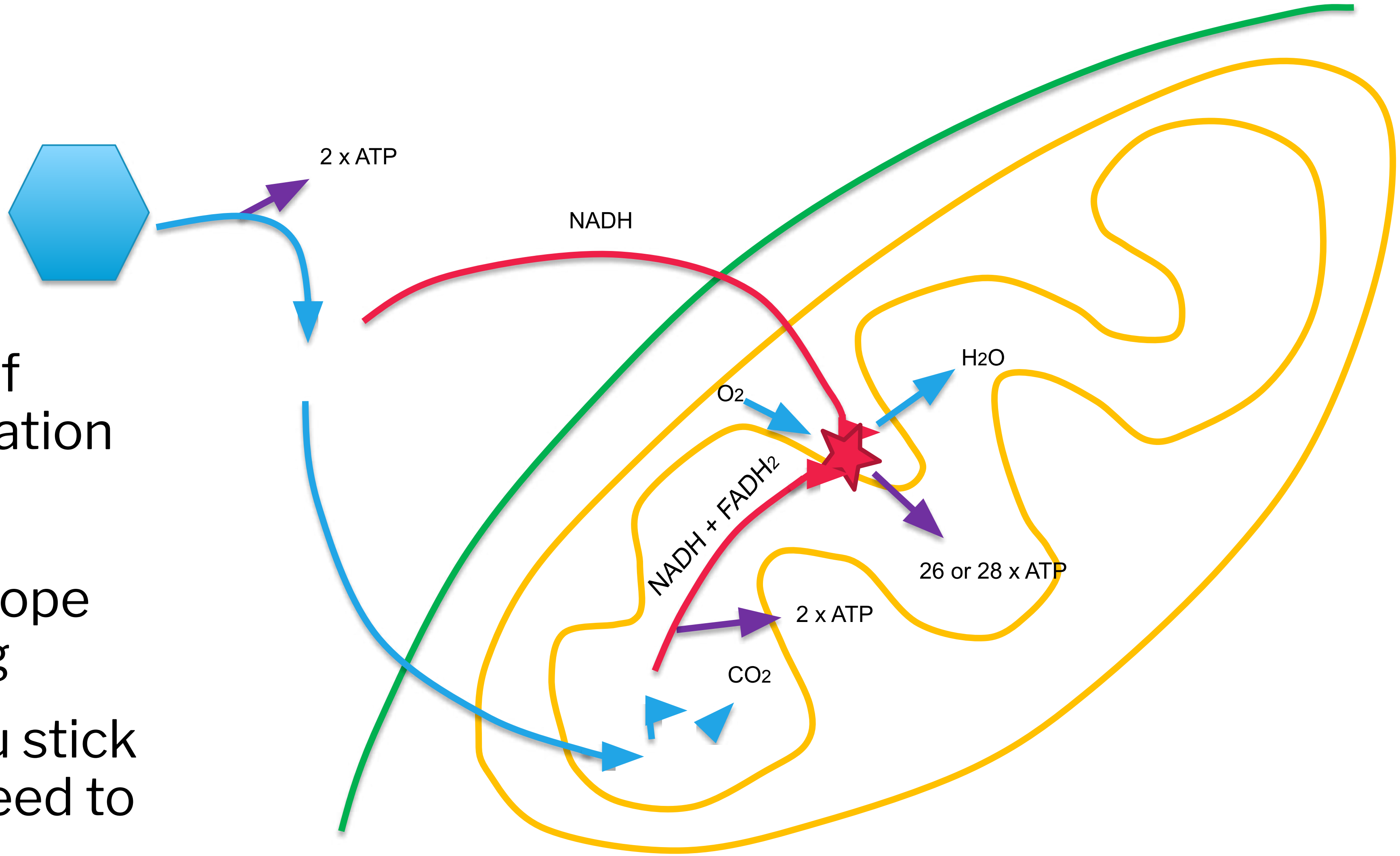
- For the scope of Chemistry, you must know:

*Glycolysis → Kreb Cycle → Electron Transport Chain*

$$C_6H_{12}O_{6(aq)} + 6O_{2(g)} \square\ 6CO_{2(g)} + 6H_2O_{(l)}$$

- What is interesting about the inputs and outputs?

# Complexity of Aerobic Respiration




- The process of aerobic respiration is extremely complex and beyond the scope of our learning
- Make sure you stick to what you need to know

## What about oxygen?

- Now the natural cycle of glucose and energy must occur in the presence of oxygen, what if oxygen was not present?
- We refer to this as **Anaerobic Respiration / Fermentation**, a process that is utilised in the production of biogas and bioethanol
- Organisms go through anaerobic respiration where **lactic acid** or **bioethanol** is produced as a bi-product
  - Yeasts and Bacteria = **Ethanol**
  - Multicellular organisms (eg// humans) = **lactic acid**
- We will focus on **bioethanol** as a product

# Fermentation


- Yeast
- Glucose

$$C_6H_{12}O_{6(aq)} \rightarrow 2C_2H_5OH_{(aq)} + 2CO_{2(g)}$$

- The issue with bioethanol is the form it is produced in, **aqueous**
  - Bioethanol is not pure and is contaminated with water
  - As such we must purify the fuel via **distillation** to ensure that is pure
  - This process involves boiling the fuel through pipes, condensation of different components at different temperatures occurs to purify much like **fractional distillation**

## Practice Question

Bioethanol is produced by the anaerobic breakdown of biomass (largely waste plant matter) by microorganisms. It is largely a renewable fuel source, because the feedstock for its production (plant matter) is constantly replenished by the natural process of plant growth.

Bioethanol is often described as a ‘carbon-neutral’ alternative fuel. With reference to the processes of bioethanol production, explain why the ‘carbon-neutral’ label is justified. (3 marks)

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$CO_2$ released in fermentation (as described below) and combusted was initially removed from the atmosphere via photosynthesis. (1 mark)

$C_6H_{12}O_{6(aq)} \rightarrow 2C_2H_5OH_{(aq)} + 2CO_{2(g)}$ (1 mark)

Therefore, there is no net addition to atmospheric $CO_2$, so bioethanol is carbon neutral. (1 mark)

ATAR Notes

# GOOD LUCK <3